# PSYCHOLOGY TEACHERS UPDATE

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## COGNITIVE NEUROPSYCHOLOGY

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# PSYCHOLOGY TEACHERS UPDATE

Psychology Teachers Update is designed to give a brief overview of the main developments in the different areas of psychology. There is a proliferation of journals and research, and it is very difficult to keep abreast of the latest trends, particularly in the many and varied areas of psychology.

Each issue of Psychology Teachers Update will cover a particular topic, and summarise the main research directions and findings in the last ten to fifteen years approximately. The aim is to give teachers the feel of what is happening in that area of psychology.

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Forthcoming topics include consumer psychology; consciousness; and critical psychology and psychiatry.

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# INTRODUCTION

Cognitive neuropsychology seeks to understand the brain and cognitive functioning from studying brain injured and brain damaged individuals.

Ellis and Young (1988) summed up the aims as:

a) "to explain the patterns of impaired and intact cognitive performance seen in brain-injury patients in terms of damage to one or more of the components of a theory or model of normal cognitive functioning", and

b) "to draw conclusions about normal intact cognitive processes from the patterns of impaired and intact capabilities seen in brain-injured patients" (p4).

Underlying cognitive neuropsychology are certain key assumptions:

i) Modularity of the brain - Research on case studies of brain damaged patients has been used with the modular model of human brain evolution. This is the idea that the human brain evolved as a number of separate units or modules carrying out specific functions rather than as a whole unit: "it is a collection of devices that assists the mind's information processing demands" (Gazzaniga 1998).

ii) Neurological specificity - There is a correspondence between the organisation of the mind (cognitive abilities) and the organisation of the brain. This assumes the localisation of functions in the brain (isomorphism).

iii) Damage affects different modules in the brain selectively, and performance on cognitive tasks show evidence of which module(s) damaged.

This is shown with double-dissociation. Damage to area x disrupts behaviour X but not behaviour Y, whereas damage to area y disrupts behaviour Y but not behaviour X (Toates 2004).

Intensive single-case studies of brain injured patients are the mainstay of cognitive neuropsychology, both those where injury has naturally occurred (eg: stroke, accident) or where it was surgically induced (eg: split-brain operations).

# SPLIT-BRAIN PATIENTS

In the late 1950s and early 1960s, a radical operation was tried for a few individuals with intractable epilepsy. It involved cutting the corpus callosum which links the two hemispheres of the brain, and thus stopping communication between the two sides of the cortex. The original operations took place in California (Bogen et al 1965).

These original patients and later ones have been studied quite extensively over the last forty years. The methods of study have improved with time, but the principle of testing remains the same. Information is shown to one eye (visual field) at a time: stimuli in the left visual field go to the right hemisphere and the right visual field to the left hemisphere.

The key finding of the original research by Roger Sperry (Sperry et al 1969) and Michael Gazzaniga (Gazzaniga 1970) was that each hemisphere of the brain has different abilities. The work with split-brain patients confirmed earlier findings with animals (eg: Myers 1956) and established the fact of hemispheric specialisation or brain lateralisation. For example, the speech centre of the brain resides in the left hemisphere. This means that when information is presented to the right eye, the split-brain patient can say what they see, but not when the information is presented to the left eye. However, in the latter case, they can point to the correct information.

Communication of perceptual information cannot take place between the two hemispheres in split-brain patients. This contradicted earlier studies with humans (eg: Akelaitis 1941), though it is not clear if the whole corpus callosum was severed in these cases. However, some information does seem to be communicated (cross-integration) between the hemispheres - eg: "crude spatial location information" (where objects are in the visual field) (Gazzaniga 1995).

The lack of cross-integration can be seen in this type of experiment (Kingstone et al 1995). Simultaneously two words are flashed on the screen, one seen by each eye, like "hot" and "dog". The participants are asked to draw what the word means. Normal participants draw a "hot-dog" (frankfurter in a bun) because they have integrated the two words into an overall meaning. The split-brain patients tended to draw a dog that is hot (ie: separate meanings).

ATTENTION

In terms of focusing attention on a particular object, this is not affected by the split-brain because the brain mechanism used is common to both hemispheres. So they cannot get the right hemisphere to focus to the left visual field while the left hemisphere simultaneously focuses attention to the right visual field: "Thus, like neurologically intact observers, the attentional system of split-brain patients is unifocal. They are unable to prepare for events in two spatially disparate locations" (Gazzaniga 1995 p219).

Experiments have been devised to test the attentional capacity of split-brain patients. The original experiment (Holtzman and Gazzaniga 1982) presented different information to each visual field with the task of recalling the objects shown. In the "hard" condition, each eye was presented with three different geometrical shapes, while in the "easy" condition, one eye was shown three different shapes and the other eye the same three shapes.

The "hard" condition requires more overall attentional resources and the accuracy of recall will be poorer if attention is a central capacity. The "easy" condition requires less attentional resources and recall should be more accurate. This is what was found. If attention is allocated by each hemisphere separately, then there should have been no difference between the conditions.

But split-brain patients can search for visual targets in parallel, which is not possible for normal participants. The task usually set is to find a letter (eg: "T") among a group of others (eg: "C"). Length of search can be measured (reaction time), and this increases with the number of items on the screen. Normal participants take an average 70 milliseconds longer to find a target with every two items added to the group (Gazzaniga 1995). If split-brain patients are presented with a large group of items to search for a target across both visual fields, they take almost half less time (Luck et al 1989) [1]. The only way that these individuals could find the target quicker among the group of items is that the two disconnected hemispheres are searching separately and in parallel (Gazzaniga 1995).

However, the hemispheres are not searching equally as well because each hemisphere uses a different strategy

[1] Patient JW took approximately 500 milliseconds to find a target among a group of three items, and marginally longer among a group of sixteen items, while controls took averages of 300 and 900 milliseconds respectively (Gazzaniga 2000).

with the left, dominant hemisphere being "smarter" (Kingstone et al 1995).

Other differences in visual perceptual abilities have been found between the hemispheres. Corballis et al (1999) presented two shapes on a screen in each visual field. When the task was to judge if the shapes were the same ("identity" condition), the left hemisphere performed slightly better. If the task was to judge the relative position on the screen of the two shapes ("spatial" condition), the right hemisphere was better.

## MEMORY

Memory is not a simple recording of factual events, it can include inferences and connections. Work with split-brain patients has shown hemisphere differences in recall of unpresented related material. The left hemisphere includes "interpolations, extrapolations, and inferences that it adds" to the memory for the event, while the right hemisphere tends to recall the event more accurately (Metcalfe et al 1995).

Phelps and Gazzaniga (1992) showed split-brain patients a sequence of twenty slides of an event, like a woman baking cakes, in each visual field. Then there was a recognition test for the original slides from sixty slides - 20 original, 20 similar slides (schema-consistent; eg: same woman baking something else) and 20 unrelated. There was no hemisphere differences in recall of original slides or unrelated ones, but the left hemisphere was more likely to recall the schema-consistent slides as part of the original group. The left hemisphere is generalising the information shown and this influenced the relevant slides (schema-consistent). This fits with the idea that general memories of a common event are recalled rather than specific memories of that event.

Generally, split-brain research shows that the left hemisphere is better at semantic memory tasks and the right hemisphere at episodic memory (Gazzaniga 2000). Both hemispheres have both abilities, but it is degrees of advantage rather than complete specialisation as with language.

## LANGUAGE

Language resides in the left hemisphere usually, but a small number of cases of split-brain patients (3 or 4; Gazzaniga 2000) develop language abilities in the right hemisphere after the operation. However, it was not equal

in standard to the left hemisphere ability (eg: one word utterances only; Gazzaniga et al 1979). This showed a plasticity of the brain even ten years after the operation.

## MAKING SENSE OF BEHAVIOUR

The left hemisphere has been called the "interpreter" because it provides an explanation for the patient's behaviour. For example, a picture of a chicken claw is flashed to the left hemisphere while a picture of a snow scene is shown to the right hemisphere simultaneously. The patient is asked to choose the two pictures from an array that are relevant; in this case, a chicken and a shovel (for the snow). Split-brain patient PS was asked why he chose those pictures, and he replied: "'Oh that's simple. The chicken claw goes with the chicken, and you need a shovel to clean out the chicken shed'. Here, the left brain, observing the left hand's response, interprets that response into a context consistent with its sphere of knowledge, one that does not include information about the left hemifield snow scene" (Gazzaniga 1995 p225).

This process has been linked to how false memories develop (Gazzaniga 1998).

Thus the left hemisphere is dominant for hypothesis formation, though this can be less effective in probability guessing games. Wolford et al (2000) asked split-brain patients to guess whether a red or green stimulus would appear next on a computer screen. The two colours were presented randomly, but overall 75% of the time red and 25% green. The right hemisphere did better on the task because it used the strategy of guessing the same colour every time (which is what rats do). The elft hemisphere tried to form hypotheses about the pattern of presentation and guessed different colours each time, thus doing poorly.

Brain lateralisation is relatively unique to humans, and the monkey brain shows few signs of it. Gazzaniga (1998) argued that in evolution this process is a sign of hemispheres losing an ability, not gaining it, in the "fierce competition for cortical space". Corballis et al (quoted in Gazzaniga 1998) found differences in how each hemisphere responded to certain types of visual illusions in split-brain patients. A number of lines together can appear meaningful because of perceptual grouping (eg: lll ll ll). Rather than seeing seven individual lines, we perceive three groupings. The right hemisphere is better at this ability, while the left hemisphere seems to have lost it as mice are able to perceive the groupings (Gazzaniga 1998).

## PARTIAL SPLIT-BRAINS

Work with patients with staged or partial cutting of the corpus callosum has shown that specific regions of the callosum transfer specific information. For example, visual information can still be transferred between hemispheres when the splenial region (posterior area of the callosum that connects the occipital lobe) is not damaged, while the anterior region transfers auditory and tactile information (Gazzaniga 1995).

Posterior only partial split-brain patients have free recall problems which anterior only do not. The posterior callosum links the hippocampus and this may explain these findings (Gazzaniga 1995).

## EXAMPLE OF A SPLIT-BRAIN PATIENT - JW

JW is a right-handed male, who underwent a two-stage callosotomy (severing of the corpus callosum), at age 25, for pharmacologically intractable epilepsy. The posterior half was first cut, and the anterior part ten weeks later by Dr.Donald Wilson of Dartmouth Medical School (Gazzaniga and Smylie 1984). His IQ was measured as average (95-102) in 1989 (Metcalfe et al 1995).

JW was studied both during the partial and after the full split-brain operation. There were differences found in the transfer of information between the hemispheres during the partial phase. If shown a word to the left eye, the full split-brain patient will say that they cannot see anything because the right hemisphere does not have speech. JW, with the anterior half of the callosum intact, could not name the word if shown to the left eye, but could talk about the meaning of the word until it was worked out. Thus information (higher order - meaning) was being transferred to the left hemisphere (Sidtis et al 1981). For example, when shown the word "knight", he replied: "I have a picture in mind but can't say it.. Two fighters in a ring.. Ancient.. wearing uniforms and helmets.. on horses.. trying to knock each other off.. Knights?" (Gazzaniga 1995 p222). After the full split-brain operation, he could not do this.

Holtzman and Gazzinga (1985) found that JW could outperform normal participants on certain types of memory tests. The experiment involved showing a matrix containing a target "X" for 150 milliseconds, and then participants had to say if the following matrix was the same or similar. But when two different matrices were presented simultaneously, one to each visual field, JW did significantly better than the controls. Normal

participants tended to perceive the two matrices as a whole while JW could not combine the information and this proved an advantage. The split-brain operation "turns a unified perceptual system into two simpler perceptual systems that do not interact and therefore do not interfere with each other" (Gazzaniga 2000).

Metcalfe et al (1995) tested JW extensively, at the age of 41, in relation to memory accuracy between the hemispheres. They predicted that the right hemisphere should recall more accurately than the left.

a) JW was presented with random six dot patterns on a computer screen to learn. Then there was a recognition test including the original patterns, similar ones, and dissimilar ones. The task was performed separately for each eye. The left hemisphere was more likely to recognise the similar patterns as the original ones than the right hemisphere. JW was asked to point at the correct answer to remove the influence of speech in the left hemisphere.

b) The right hemisphere also showed better recognition of faces. Children's faces were presented, and recognition was tested with the original, composites (two faces superimposed), and unseen faces.

c) Memory for words was also tested. The left hemisphere recalled more same category words (ie: not shown in original but similar meaning) than the right.

d) This experiment showed JW pictures relating to words, and the recognition test involved words related to the pictures or similar and dissimilar ones. The left hemisphere was better at this task because of the apparently "superior word knowledge in the left hemisphere".

The researchers concluded that "the right hemisphere stores more exact memory traces than does the left hemisphere. Human cognition includes generalisations, conjectures, inferences, and fantasies, all presumably, being enacted primarily in the left hemisphere.. We suggest that it may be that this more veridical right-hemisphere memory system may have a critical adaptive function - allowing the interpretations, interpolations, and inferences of the left hemisphere while still maintaining an accurate record of the past" (p163).

Turk et al (2002) tested JW's face recognition abilities, at age 48. Eleven morphed faces were computer generated from JW's and a familiar person's (MG) face varying from 100% JW/0% MG to 0% JW/100% MG. The images were presented to each hemisphere for 250 milliseconds in

a random order, and JW had to press a button to respond if self or other. The left hemisphere was better at recognition of the self and the right hemisphere had recognition bias for the familiar other (table 1).

The same results were found with morphed faces of JW and PC (personal friend), JW and Bill Clinton, and JW and George Bush.

| | LEFT HEMISPHERE | RIGHT HEMISPHERE |
|---|---|---|
| Self recognition:<br>30% JW/70% MG | 0.3 | 0.05 |
| Other recognition:<br>30% MG/70% JW<br>70% MG/30% JW | 0.1 | 0.4 |

(After Turk et al 2002)

Table 1 - Approximate proportion of correct responses by JW based on morphed face of JW and MG.

Contrary to expectations, JW developed the capacity to speak from the right hemisphere thirteen years after his surgery (Gazzaniga 1998). Thus he is able to say what he sees presented to either eye. However, this ability did not "confer the full complement of cognitive skills associated with the language processing skills of the left hemisphere" (Gazzaniga and Smylie 1984).

Interestingly, JW is an expert at the assembly of model cars which requires the co-ordination of both hands as well as planning (Gazzaniga 2000).

# BLINDSIGHT

Blindsight is "visual discrimination in the absence awareness" (Weiskrantz 1996), and was first coined by Weiskrantz et al (1974) [2].

Individuals with damage to the V1 area of the primary visual cortex [3] report blindness or blind spot/scotoma (while the eyes are undamaged), but when forced to choose between two visual stimuli, they guess correctly most times; much more than by chance.

Depending on variables like size, colour, onset time, and speed of movement of stimuli, patients' performance has been found to vary from chance to moderately statistically significant to 100% correct despite no conscious awareness of the stimuli (Stoerig and Cowey 1997).

Many of the patients have damage to specific areas of the visual field or to one visual field only. They are known as hemianopic patients (Milner 1998) [4].

One of the best known cases is DB (an English man born in 1940), who received damage to the right side of part of the visual cortex (striate cortex) during brain surgery. The consequence is that DB is blind in his left visual field. He could reach accurately for visual stimuli, differentiate the orientation of lines, and distinguish "O" from "X" in his left visual field despite no conscious perception. In the latter case, he distinguished "X" from "O", and a square from a diamond at over 75% correct, but less accurate for a square and a rectangle (Weiskrantz et al 1974).

Blindsight is counter-intuitive and the initial response to findings was negative - maybe the patients were not completely blind. Weiskrantz et al (1986) quoted evidence that ruled this possibility out, and subsequent neuroimaging technology has confirmed this.

Research has found that patients can also discriminate orientation and direction of movement of targets in their blind fields as well as the perception of colour, but not complex movements or fine detail (Martinez-Conde 2008). Patients are presented with a colour in their blind field and asked to choose from two answers. GY, for example, named the correct colour on

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[2] The term is controversial (Milner 1998), and Zeki and ffytche (1998) preferred to use the term "agnosopsia".

[3] Also includes individuals with damage to the optic radiations which connect the lateral geniculate nucleus to the cortex (Milner 1998).

[4] Ptito and Leh (2007) discussed the case of blindsight after hemispherectomy (removal of one hemisphere of the brain).

most occasions without the conscious perception of colour (Brent et al 1994).

This is forced-choice guessing which is the main way of testing visual perception. Sometimes the instructions for such experiments are confusing; eg: "Whenever you are conscious of the light going on, press the button on the left; whenever the light goes on but you are not conscious of it going on, press the button on the right" (Dennett 1991 p328).

Indirect methods have also been developed including (Weiskrantz 1990):

a) To measure the effect of information in the blind field on the intact visual field. Some patients have sight in one visual field and not in the other. In this case, the patients are asked to press a computer key as soon as an image appears on the screen in their visual field. The average reaction time is measured. This reaction time will be quicker if a hint is presented to the blind field before the image appears in the visual field. The patients report no visual stimuli in the blind field, though.

b) Physiological measures, like electrical skin conductance, independently show a response to the "unseen" stimuli despite no conscious perception.

Recent research suggest that blindsight individuals can learn to "see" with practice. Sahraie et al (2006) asked twelve patients with blindsight to guess between two stimuli (dot or grating) in their blind field. Initially, the correct guesses were low, but this increased to 25% after three months of daily practice.

In a bizarre twist, blindsight may actually be better than normal sight. Trevethan et al (2007) asked DB to say when a grey patch appeared on a grey background ("Gabor patch"). During 150 presentations, DB was correct 87% of the time in the blind field, but less than chance in the sighted field. DB has normal sight in his sighted field. But "DB is probably a particularly gifted patient, from all his experience, he may have developed an intuitive sense for when something is going to appear - and may have learned to trust his intuition" (Martinez-Conde 2008 p53).

As research with blindsight patients developed, it led to the distinction of Type I and Type II sub-categories (Weiskrantz 1989). Type I blindsight patients have no awareness in their blind field, whereas Type II patients do.

Danckert and Rosetti (2005) preferred the sub-categories of:

- "Action blindsight" - ability to point to or grasp a target in the blind field;

- "Attention blindsight" - ability to detect movement in the blind field (and it may or may not involve conscious awareness of the stimuli);

- "Agnosopsia" - ability to guess the correct characteristics of the target, like colour, despite no conscious awareness of it.

Work has been done with monkeys and blindsight, where areas of the brain are deliberately damaged. The response of the animals to visual testing has to be assumed. Gazzaniga et al (1994) argued that such experimental results are not generalisable to humans. Human cases depend on naturally occurred injuries where damage is varied (ie: not just to a specific area), and the age of the injury. What it does mean is that a small number of patients have been studied very intensively.

The study of blindsight has shown that the visual pathway from the retina to the visual cortex (V1 area) via the dorsal lateral geniculate nucleus (LGN) [5] is not the only one involved in visual perception. Information from the retina goes in parallel to at least nine other pathways in the brain including the superior colliculus and the supra-chiasmatic nucleus (Weiskrantz 1996) [6].

The second major visual route goes from the eye through the superior colliculus in the midbrain and pulvinar nucleus of the thalamus (Milner 1998).

Among the researchers into blindsight, there are a number of debates (Milner 1998):

i) Do patients have "islands of intact cortex within area V1" which would explain the remnants of vision? Weiskrantz (1996) tended to argue against this possibility.

ii) Does different types of visual information (eg: colour, movement) travel along different pathways through the brain, and if so, which pathways for which information?

iii) What does blindsight tell us about perception, attention, and consciousness?

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[5] Known as the "dorsal stream" as opposed to the "ventral stream" where information passes through the ventral LGN.

[6] Stirling (2000) suggested at least 30 different areas in the cortex are involved.

Milner and Goodale (1995) proposed that conscious visual perception uses information via the "ventral stream", and perception without awareness via the "dorsal stream". The former is "what" information, and the latter is "where" information and movement. This is faster and linked to survival - escape before aware what is coming (Datta 2004).

Chris Frith (1999) sees blindsight as an example of "non-conscious skills" used all the time without noticing. Other unusual conditions include "deaf-hearing", "numb-touch" (eg: Paillard et al 1983; case of woman with left parietal cortex damage), and amnesiacs who can remember without knowing.

Garde and Cowey (2000) reported a case of deaf-hearing with a 26 year old Spanish woman called IA who received brain damage from a car accident. This produced cortical deafness (ie: deafness due to damage to the auditory cortex not the ears). When asked if a sound had been made, she said she heard nothing, but when forced to guess, scored twelve out of twelve correct. She scored six out of twelve for discriminating the ear to which the sound was played.

## EXAMPLE OF BLINDSIGHT CASE - GY

GY (or Graham) is a man born in 1956 who suffered damage to his left V1 area after a head injury in a road accident at eight years old (Weiskrantz 1996). He ran in front of a car and received a near-fatal blow to the back of his head (Concar 1988). This has produced right hemianopa. This is blindness in his right visual field because information from the right side goes to the left hemisphere and vice versa.

A PET scan showed no activity in the V1 area in response to visual stimuli, but activity in other areas of the visual cortex (Barbur et al 1993).

GY shows a high level of visual ability in his blind visual field. For example, he can follow a moving target and describe its path with his hand despite not consciously seeing the target.

The nearest thing to conscious perception in GY's blind field is the sensation "that something happened" for very bright stimuli, flashing objects, and quick movement. With rapidly moving stimuli, GY has reported knowing the movement and direction despite not seeing it. This has led to the idea of "conscious visual perception without V1" (Weiskrantz 1996).

Weiskrantz et al (1995) used the "commentary key" paradigm to test GY. This technique involves four keys to press: two for the direction of the moving stimuli, and

two for how much he was aware of the stimuli. Correct discrimination of the direction of the stimuli was never less than 80% irrelevant of the reported awareness. At low speeds, GY reported no conscious awareness but was over 90% accurate, and at high speeds the same accuracy but with conscious awareness of the movement. In another condition, the background luminance was varied for the moving object. GY's accuracy of the direction of movement hardly varied as the background contrast was changed even as conscious awareness decreased.

de Gelder et al (2001) used another technique called the "redundant target paradigm" to test GY's recognition of facial expressions in the blind field. This technique involved showing two faces (one to each eye) to the participant. The task is to say if the facial expression in the blind field is the same as the one in the healthy visual field. The reaction time of response is usually quicker for congruent faces.

Kentridge et al (1999) were interested in the question of whether attention and awareness are linked. The reaction time of GY's response was used in this set of experiments. An auditory tone was presented, and then a target or not to the blind field. In half the trials, there was a target and in half not.

When there was a target, there was also a visual hint beforehand in some trials as to where the target would appear on the screen. For healthy controls, this hint produces selective attention to the area of the screen, and reaction time is faster.

GY was faster to respond and more accurate in detailing the presence of a target. This is taken as selective attention without awareness. If GY was not focusing his attention there should be no difference in accuracy when the visual hint was misleading, but there was a significant difference (table 2).

Schurger et al (2008) used the same methodology, but magnetoencephalography (MEG) recording was made during the experiment. MEG records neural activity. A particular pattern of electrical activity was measured for attention with or without awareness.

Interestingly, GY does not show any spontaneous intentional behaviour towards objects in the blind field. For example, he would not reach for an object in his blind field unless told to do so (Datta 2004).

Because GY's damage to the visual cortex occurred at a young age, there is some concern over whether his brain adapted after the accident ("experience-dependent plasticity")(eg: Cowey 2004).

1. Visual cue - arrow pointing to one area of screen - before target: produces selective attention; predict reaction time faster and accuracy better.

2. Visual cue misleading - arrow pints to wrong area of screen or no target appears afterwards; attention focused by arrow and so predict reaction time slower and accuracy poorer for target.

- No selective attention = no difference between the conditions.

| | REACTION TIME | ACCURACY |
|---|---|---|
| Condition 1 | approx 800 ms | 69% (632 of 915 trials) |
| Condition 2 | approx 1000 ms | 53% (190 of 358 trials) |

Table 2 - Conditions, expected and actual results of Kentridge et al (1999).

## MEMORY AND HM

Since becoming amnesic in 1953, HM has been studied by nearly one hundred different investigators, mainly from the Montreal Neurological Institute and Massachusetts Institute of Technology (Corkin 2002). The case study being most widely reported as Scoville and Milner (1957).

He suffered from minor epileptic fits from age 10, and these became more severe from age sixteen. This led to the experimental surgery by William Beecher Scoville on the medial temporal lobe (MTL). It involved the removal of approximately two-thirds of the MTL on both sides of the brain, which included the hippocampus and amygdala.

Scoville and Milner (1957) linked H.M's amnesia to the removal of part of the hippocampus. They were among the first to make this link.

Research on H.M, over the years, has concentrated upon a number of questions about memory, and some of the initial conclusions have been challenged: for example, that the hippocampus was the site of the long-term memory. It is now felt that the hippocampus is where memories are formed (physiologically), and then transferred over several days to the "cerebral cortical storage system" (Murphy and Naish 2004).

i) Was the amnesia evident irrelevant of the type of memory test (eg: free recall or recognition), the stimulus material (eg: word or digit), and the senses used (eg: viewing or listening to stimulus material)?

The answer, after many different researchers have tested all of these elements, is yes (Corkin 2002). HM has no long-term memory after the operation: both forms of declarative memory - episodic and semantic. For example, HM cannot remember the meaning of new words learnt after the operation.

ii) What memory abilities are still intact?

HM's short-term memory appears to be in full working order. While extensive studies by Milner et al (1968) felt that his comprehension of language is "undisturbed". Corkin (1984) did challenge this, by suggesting he had a "mild language disorder", but this "might have preceded the brain operation" (Corkin 2002).

Recent research by Kensinger et al (2001), on his lexical memory (memory for words) and grammatical processing, found normal scores for his age and education

level. Corkin et al (1997) argued that any language problems could be due to additional damage to the MTL in the lateral temporal neocortex.

iii) Can H.M learn anything?

Despite the memory problems mentioned above, Brenda Milner in 1962 (Corkin 2002) was the first to report evidence of learning by HM on a mirror-tracing task. This task involves tracing a picture of a star from the reflection in a mirror, where left and right are reversed. Generally individuals improve on this task with practice. H.M showed such improvement, but had no conscious recall or recognition of ever having done the task before. Any improvements lasted as long as a year (Corkin 2002). These findings showed that the acquisition and retention of skills is in another part of the brain than the MTL.

But his performance on a maze did not improve even after 215 trials (compared to the seventeen trials needed by healthy volunteers to learn the route) (Milner 1965). This task is more of a pure memory task than the mirror-tracing one.

Another area of learning where HM showed some normal progress is known as priming repetition. This is tested by giving participants a stimulus to study (eg: list of words), and later word stems, for example, to complete. The previous stimulus will influence the subsequent task, but unconsciously. For example, reading about lighting devices will influence the word stem "CAN" to be completed as "candle" more often than "cannot", "canned", or "cannery".

HM has the normal abilities for word-stem completion with familiar words, but not unfamiliar words (Postle and Corkin 1998).

Postle and Corkin devised a word-stem completion task for HM using words that had entered the dictionary after 1965 (ie: after HM's operation). HM was asked to read aloud each word on a computer screen, and then one minute later to complete a three-letter word stem with the first word that came to mind. He tended to complete the word stems using words learnt pre-operation rather than the new words just read. For example, HM read the new word "fractal", and then later given the word stem "FRA". Non-amnesic participants usually give "fractal", while HM was more likely to choose another word like "fraud" (Corkin 2002).

iv) Was there evidence of new memories after the

operation?

Corkin (2002) reported, from her extensive work with HM, evidence of topographical memory (or personal semantic memory) formed after the operation. In 1958 (five years after the operation), HM and his parents moved to a new house in Connecticut (where he lived until 1974). In 1966, he was able to draw an accurate floor plan of the house. Asked, in 1976, to do the same thing, he again drew an accurate plan of this house not the new one where he was now living with his mother and another relative.

Corkin (2002) felt that his recall of the house plan was because of the information "being learned slowly over an extensive period of time, presumably with the support of cortical structures" (p156). In other words, HM had constructed a cognitive map of the house's layout. McNaughton et al (1991) proposed that spatial processing involves a number of areas of the brain, of which most were intact in H.M (eg: area 7 of the posterior parietal cortex).

Another contrary finding for HM was his normal ability to recognise coloured magazine pictures (seen for twenty seconds) at ten minutes, 24 hours, 72 hours, one week, and six months (Freed and Corkin 1988). This ability is familiarity judgement rather than recall, and uses other parts of the brain again (eg: perirhinal cortex).

Kensinger and Corkin (2000) tested HM on recognition of famous faces from the 1920s to 1980s. The task was to name the face, the reason for their fame, and their decade. For pre-operation faces (1920s and 30s), HM was significantly better than healthy volunteers, and significantly worse for the 1950s onwards (post-operation). Concentrating on the later faces, HM was given extra cues:

a) Semantic information about the face; eg: President of USA. This did not improve recognition scores;

b) Phonemic cues (eg: initials). HM's naming of faces did improve (though still below that of healthy volunteers), but not their reason for fame or decade. Thus HM did have some semantic memory, even if poor, for the post-operation period.

The most outstanding finding on memory from the years of study is that memory is made up of many different types which use different areas of the brain (either alone or in combination). There is no simple situation of memory/amnesia (no memory).

# VISUAL AGNOSIA

Visual agnosia is the inability to recognise objects due to damage in the brain not the eyes. "The consciously perceived visual world is very different from the raw visual information or retinal mosaic of intensities and colours that arises from external objects" (Behrmann and Kimchi 2003 p19). The latter is turned into the former through the processes of perceptual organisation. Visual agnosia is manifested in problems in these processes.

It was first noted in 1890 by Lissauer, and prosopagnosia by Bodamer in 1947.

Visual agnosia covers a range of deficits including the inability to find a vertical line among horizontal ones, at one end, to those who perceive an object but cannot recognise it (visual object agnosia)(Behrmann and Kimchi 2003).

Lissauer (Jackson 1988) made the distinction between apperceptive agnosia ("a deficit in the initial stages of sensory processing in which the perceptual representation is constructed") and associative agnosia ("a deficit in mapping the final structural representation onto stored knowledge"; Aviezer et al 2007). Individuals with associative agnosia can copy complex drawings, but not identify objects drawn. With apperceptive agnosia, individuals cannot copy even simple shapes, but can name them (Murphy and Naish 2004).

However, Farah (1990), for example, has questioned these distinctions.

Case studies with individuals diagnosed with visual agnosia find quite different patterns of disability. For example, LH could not recognise faces, but could recognise objects except for some problems with animals (Etcoff et al 1991). While the opposite was the case of man who could recognise faces, even disguised, but not everyday objects.

HJA (Riddoch and Humphreys 1987) is one of the best known cases of visual agnosia. He had problems with recognising faces, objects, written words, and colours, but his abilities and inabilities varied within those. For example, he was very slow in detecting an inverted "T" among upright ones, but had no problems with finding a diagonal line among vertical ones. The latter task required less perceptual integration than the first.

It seems that objects were not recognised because the brain could not integrate perceptual information into a "global integrative gestalt" (whole picture).

Behrmann and Kimchi (2003) studied two cases of visual agnosia: SM and RN. They have some perceptual

abilities normal and some impaired (table 3).

| | SM | RN |
|---|---|---|
| Injury and age | motor vehicle accident at 18 | myocardial infarction at 39 |
| NORMAL ABILITIES: | | |
| visual acuity | 20/20 | 20/20 |
| tactile recognition | able to name objects while blindfolded | |
| Birmingham Object Recognition Battery (BORB) (Riddoch and Humphreys 1993) | sub-test of simple perceptual abilities like judging line length, orientation, size | |
| copying drawings | reasonable accuracy but took long time | |
| correct reading of words (out of 120) | 117 | 95 |
| IMPAIRED ABILITIES: | | |
| face recognition | poor | poor |
| name object (260 drawings) | | |
| - correct (%) | 66 | 51 (control 96.4) |
| - reaction time | 2.14 secs | 8.52 ms (control 885 ms) |

Table 3 - Details of cases of SM and RN.

Aviezer et al (2007) reported the case of SE, a 52 year-old Israeli man who suffered a stroke in 2004. He was unable to visually recognise common objects and faces, though tactile and auditory recognition were unaffected. He also had problems with colour perception, and orientation (eg: difficulty describing how to get home). He was tested two months after the stroke.

SE could match geometric shapes, and copy and name simple figures (eg: square). But for drawings of complex objects, he scored 26% correct recognition (eg: a mushroom mistaken for a parachute). Despite not being able to name the object, he was able to give information about the purpose of the object and copy it accurately from memory. This showed that the problem was not related to semantic memory.

In another test, an object was named and SE had to point to the correct line drawing out of five. He had a success rate of 77%.

SE was diagnosed with "integrative agnosia" (Behrmann 2003)("difficulty in binding local visual features into a unitary coherent perceptual whole"; Aviezer et al 2007), which means he had some low-level visual abilities still.

In a test with Navon hierarchical letters (Navon 1977)(figure 1), he could not recognise the global letter even when pointed out, only the local letters.

```
EEEE        YYYY
E           Y
EEEE        YYYY
E           Y
EEEE        YYYY
```

Figure 1 - Examples of Navon's hierarchical letters.

In the congruent condition (same global and local letters), shown for 450ms, SE recognised the global letter in 61% of trials and 73.4% for the local letters. For the incongruent condition, the correct trials were 33% and 73.2% respectively.

Aviezar et al tested for unconscious recognition of objects. SE was shown a drawing of an object (which he could not recognise) for 300ms, followed by a word. His task was to say as quickly as possible if the word was an animate or an inanimate object. Some preceding drawings were the same as the word, others were not. If he had unconscious recognition, his reaction time would be faster when the drawing was the same as the word.

The reaction time for the "same" condition was 2076ms compared to 2328ms for the "different" condition. So it seemed that SE had unconscious recognition of objects, and the problem was the conscious recognition of them. This was confirmed when the last experiment was repeated using scrambled drawings. Here there was no difference in reaction times between the two conditions.

Some improvements in visual recognition abilities were found when SE was tested nine months after the stroke.

SE also suffered from prosopagnosia, and could not even recognise faces known before the stroke, including famous people, family members, and himself. Furthermore, when presented with faces with parts changed (eg: apples instead of eyes), he recognised the objects but not that the stimuli were faces: "here are some fruits (pointing to the eyes).. judging by their shape, they are apples.. and these (points to nose and mouth) might be branches.. and this here (points to circular outline of face) might be a plate". But occasionally, he did "see" the face in such a stimuli when pointed out to him.

Burton et al (1991) proposed that prosopagnosia is due to a disconnection between face recognition (face

recognition units) and the feeling of familiarity (identity nodes).

A problem with testing was that SE used semantic information, like context, to aid his recognition of objects. For example, when in an office, it was noticed that he recognised a stapler, a pen, and other expected objects, but not unexpected objects. This showed that his was using top-down information in visual perception. Aviezer et al tested this experimentally.

The task was to say if a line drawing was a possible or an impossible object. Before each drawing, SE was shown a word for 1500ms. The word, known as the primer, was either for the same object or not in the following drawing. Where the word was the same as the possible object, SE was 82% accurate in naming the drawing (50 out of 61 trials), but when the word was different to the drawing, 50% accuracy (21 out of 42).

For the drawings of impossible objects, he got 69% correct but took a long time (average 13.5 seconds).

## PROSOPAGNOSIA

Neuroimaging studies with face recognition have highlighted an area of the brain called the "fusiform face area" (FFA)(fusiform gyrus at margin of temporal lobe). It seems that this area is involved in face detection (ie: distinguishing between faces and other visual objects) and face identification (ie: recognition of a familiar face, and distinguishing between different faces). The exact role in face processing of the FFA is debated, but it is involved because individuals with prosopagnosia usually have damage there (Avidan et al 2005).

Tranel and Damasio (1985) found that prosopagnosics rated familiar and unfamiliar faces as equally unknown, but showed an unconscious response, as measured by skin conductance, to familiar faces.

Behrmann et al (2005) reported cases of the "inversion-superiority effect" among individuals with prosopagnosia. Usually face recognition is longer for inverted faces than upright except in this case. Generally upright faces are processed as a whole and inverted by feature. The inversion-superiority effect is taken as an impairment in the processing of faces as a whole (Behrmann and Avidan 2005).

Behrmann et al (2005) asked participants to say, as quickly as possible, if a pair of unfamiliar faces were the same. Healthy controls took an average of 2500ms for upright faces and nearly 4000ms for inverted ones. Individuals with prosopagnosia took over 4000ms for

upright and under 4000ms for inverted faces.

A different aspect of face recognition is perception of trustworthiness. Adolphs et al (1998) found that the amygdala is important in judgement of human faces. One hundred pictures of unfamiliar faces, which had been rated beforehand on approachability and trustworthiness, were shown to three patients with complete bilateral damage to the amygdala, individuals with damage to part of the amygdala, and healthy controls. The first group were more likely to rate faces as approachable and trustworthy that had been rated as the opposite by the healthy controls. The individuals with damage to part of the amygdala were similar to the controls.

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